Space Weather Technical Forecast

Issued on Monday, 18 December 2023 at 00:41 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Risk of G1 until midweek UTC. Risk of further R1 and S1 soon much-reduced.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity, as measured by GOES16 and 18 rose to Moderate once again, with occasional C-class flares that grew in magnitude and cadence to peak at an M1.1, which was observed at 17/2017UTC from AR3514. This was the most active sunspot group of the previous week, having delivered the largest flare of solar cycle 25 so far in the form of an X2.8 on Thursday 14 December, however given its position on the extreme western edge of the disc, the sunspot group was no longer discernible to determine its classification.

This left up to eight sunspot regions on the facing side, although these were mostly small, stable and unipolar. The main exception to this was AR3519, which took the form of a Dsi/Beta near centre-disc. This group saw the emergence of an intermediate penumbral spot that then migrated westwards to join the leader in the period, although this was not capped by significant flare activity.

A filament eruption was observed on the far northeast of the disc in El Teide H-Alpha at 17/1700UTC. Whilst this has yet to be analysed, Earth impacts are considered unlikely given its emission location. A further northeast quadrant event in the form of a possibly emissive C4.8 at 17/2132UTC from a new region may yet reveal a CME, with imagery awaited. There were numerous other CMEs visible on coronagraph imagery, however these were considered to be far-sided or else limb events to no effect. No new Earth-directed CMEs were therefore in evidence.

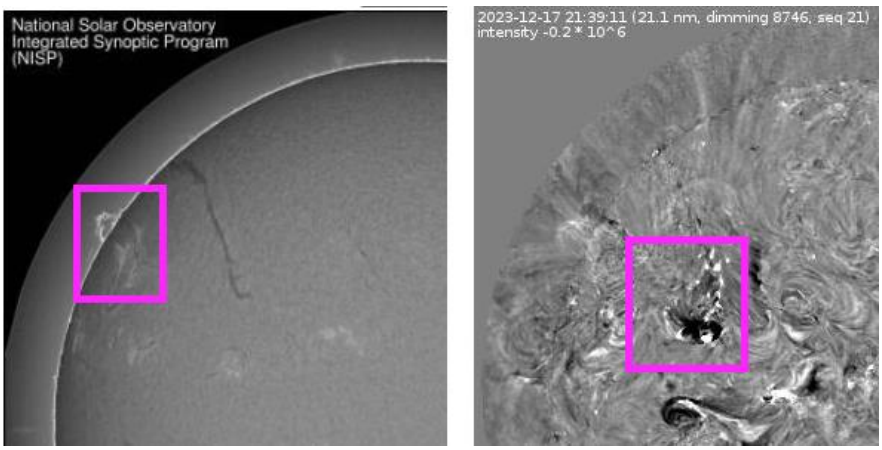

Figure 0: El Teide H-Alpha image of a disappearing filament (left) 17/1700UTC. Possibly eruptive C4.8 flare at 17/2132UTC, with minor dimming from a developing sunspot region in the vicinity. These are the main candidates for potentially relevant new CMEs in the period and are both awaiting imagery.

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Solar Wind / Geomagnetic Activity: Solar winds, as measured by DSCOVR at L1, were perhaps initially reflective of a modest positive polarity fast wind, perhaps the previously discounted CH79/+. This gave way to a CME during a brief data gap between 17/0600 and 0730UTC, thought likely to be the potentially combined front of the 14 December northwest high coronal filament eruption and the X2.8 flare from now Ex-AR3514.

The solar wind speed was initially stable between 425 and 450km/s, but saw a discontinuity during the data outage to reach 550km/s mid-morning (UTC) before waning to the high 400s into the UTC evening. The solar wind density was initially in its typical single-figure ppcc range, but saw a step-wise increase to a peak near 30ppcc that eventually relented in the final three hours of the 24. The IMF started below 10nT, but then displayed an erratic character with a peak of 17nT reached, with a north-south component of +/-14nT. The magnetic field was mainly anti-aligned with Earth's field prior to 17/1530UTC, with a switch thereafter helping to moderate geomagnetic activity. The phi angle was mainly positive (away from the Sun), but with a period of mainly negative orientation seen between 1230 and 1530UTC.

The net result of the above solar wind measures was for provisionally Quiet to Minor Geomagnetic Storm G1 conditions, with Kp peaking at '5+' in the 12-15UTC interval, while the Bz value was most strongly negative.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux was on a declining trend near resting background levels, having been raised in response to the recent larger flares from AR3514. It was below the S1/Minor Radiation Storm threshold throughout the last 24 hours, with an early peak of 1.8pfu.

GOES16 high energy (greater than 2MeV) electron flux was mostly at Normal Background levels. The 24-hour fluence was well below the Active threshold (1e8 integrated pfu) on a slightly decreasing trend. The observation at 18/0001UTC was 1.35e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: There is now a vestigial and decreased Chance of further Moderate activity and a Slight Chance of Strong, should AR3514 throw emissive ejecta clear of the western horizon that it now occupies in the first 24 hours of the forecast period. While some further active regions are likely over the eastern solar horizon into the new UTC working week, these are unlikely to adequately compensate for the loss of AR3514, and there is a step-wise moderating risk of significant flares as a result.

Solar Wind / Geomagnetic Activity: There is now one further weak possible CME in the forecast, with arrival mooted for the very end of 19 or early on 20 December. The other component of the forecast, a persistent coronal hole, is more assured, and is due on 19 December.

Geomagnetic activity carries a tail of risk of further G1 Minor Geomagnetic Storms into day one, Monday 18 December, falling to Quiet into early Tuesday. Later that UTC day, there is a possibility of a coronal hole fast wind arriving and perhaps very late on the 15 December CME, with the effects of these perhaps combining to give a peak Chance of G1 before this again wanes through midweek to leave a Quiet end to the four-day forecast.

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is now just very slightly above Background, with a Slight Chance of exceeding S1 again should AR3514 flare appropriately. This probability should then wane as this sunspot group progressively rotates from a potent position and further onto the far side.

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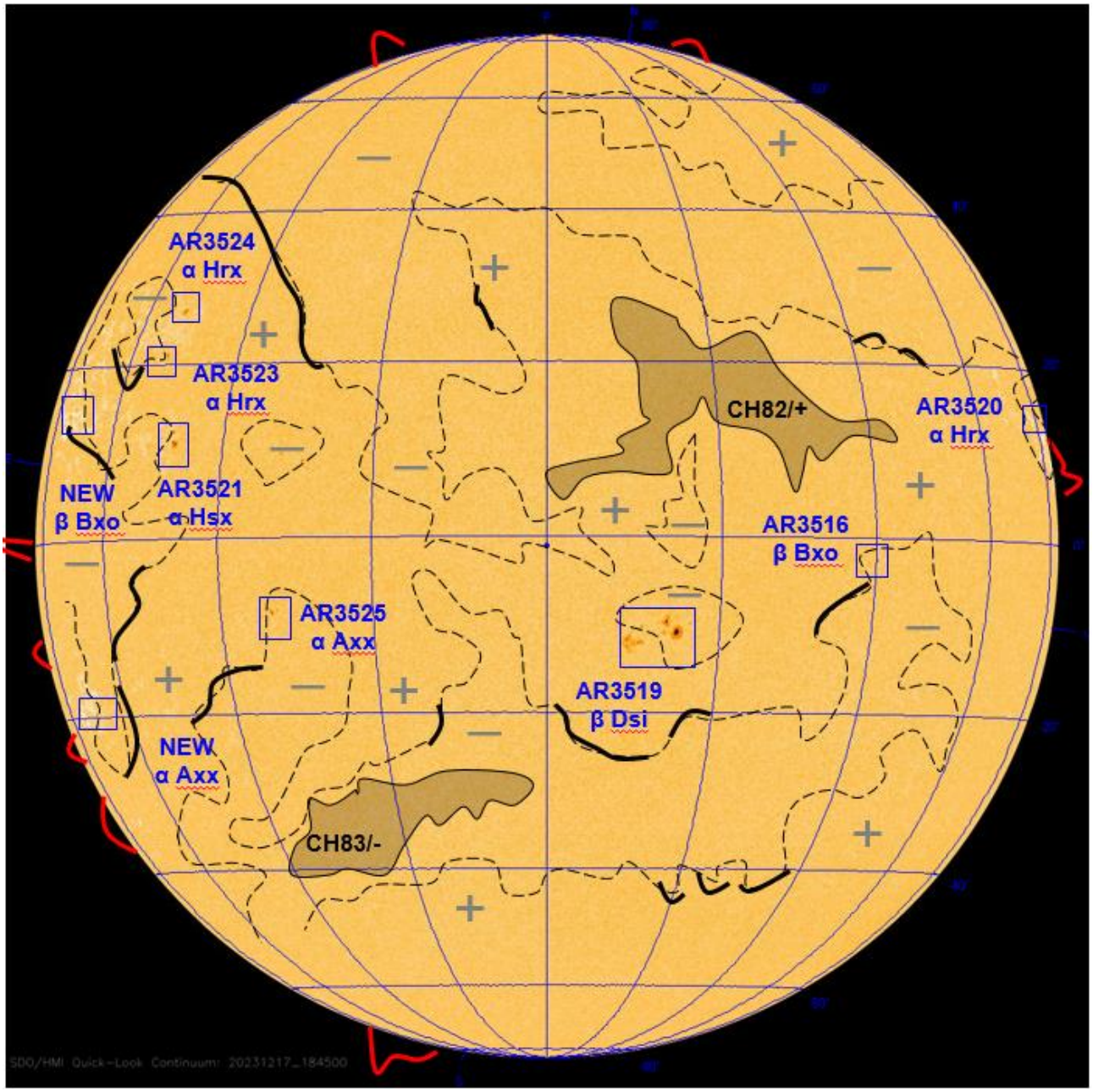
High energy electron flux is likely to be stymied at GEO by the recent CME arrival, with a brief window then arising before further attenuation by CH82/+. The associated 24-hour electron fluence should therefore mostly remain near current levels, with any more appreciable rise probably delayed until after midweek UTC given a second inbound CME due into Wednesday.

Figure 1. Solar Analysis Valid 17/1845UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

There is now one possible CME in the forecast, from the 15/2100UTC south-centre disc filament eruption. This is low confidence for two reasons - firstly the analysis used scant, faint coronagraph imagery and was only tentatively linked to the event in question. Secondly, MOSWOC Enlil is currently thought to be low and late in bringing in CH82's fast wind - the model has this as arriving after this CME, but a 500km/s intervening fast wind is preferred, as per persistence. This will accelerate the CME and could lead to arrival as early as the very end of 19 December, although the bulk of any arising effects should still occur during the previously advertised 20 December. Although error-prone, given the CME's central position, Earth impacts are considered fairly likely but probably muted for being slow and weak.

The coronal hole-driven forecast now only comprises CH82/+, due 19 December. As stated, this coronal hole had a history of a westward pointing promontory that may produce a slightly earlier onset, although this now appears to have closed. Even though we are very near the minimally-geoeffective solstice, the intensity of the coronal hole and its history of having produced a G1 on last pass both lend themselves to a further chance of similar on 19 December.

All in, the first half of the UTC working week is likely to be relatively disturbed in terms of geomagnetism, with windows of more favourable conditions generally short-lived and of low confidence - probably most reliably present after the present CME effects have waned and before CH82, i.e. perhaps later Monday 18 and early Tuesday 19 December. A latent Slight Chance of G1 should flank a peak Chance of G1 on Tuesday 19 December, largely the result of both the fast wind and perhaps an early arrival of the 15 December CME. Thursday 21 December is currently the most reliably favourable day.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	Yes	20	40	20	1
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
16/1947	Partial	Filament	S Centre	341km/s	Very late 19 December or early 20 December	Onset time low confidence.

Figure 2: Latest MOSWOC Enlil and ensemble (badge time 17/2000UTC), showing the 15 December south central filament eruption crossing 1AU. This has reduced in magnitude with time, but is still considered most liekly to arrive around the turn of the UTC day 19 into 20 December. Because the

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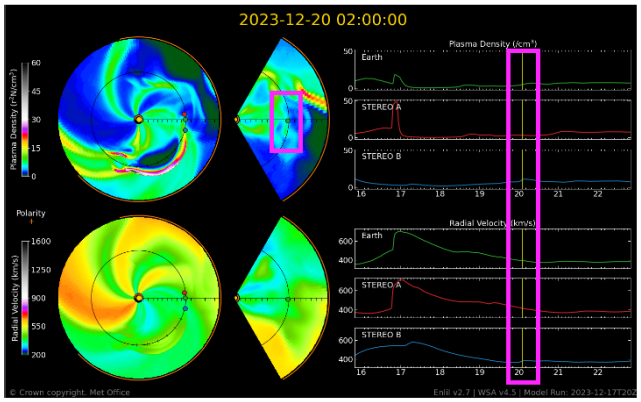
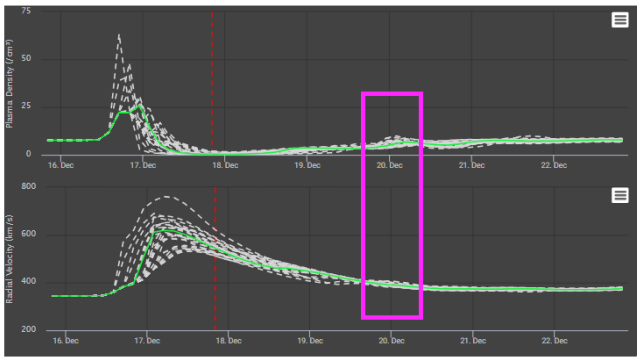
expected intervening fast wind from CH82 is absent from Enlil, there is a risk of the CME bleeding into the preceding UTC day (19 instead of 20 December) for being accelerated by the (absent in model-space) fast wind.





Radio Blackouts - X-Ray Flares:

The new UTC working week should see a page turn on X-ray activity, with the imminent passing of AR3514 onto the far side signalling a step-wise decrease in the daily Chances of significant flares. This sunspot group dominated X-ray activity of the past week - with a highlight being the largest X-ray flare since 2017 on 14 December in the form of the X2.8. The CME associated with this flare arrived in the past 24 hours to deliver G1 intervals to Earth.

The succeeding solar disc - while harbouring up to eight regions - pales by comparison to that of last week, with the vast majority of spotted regions simple, stable, magnetically unipolar affairs. There remain the returning Carrington locations of a few further sunspot regions over the eastern solar horizon in the period, however far-side soundings and limb EUV flux are not readily backed up by CME and dimming evidence to suggest anything comparable making up for the loss of Ex-AR3514.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	R1-R2 M Class	Yes	40	25	25	25
Very Active	R3 to R5 X Class	No	5	1	1	1

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Figure 3: SIDC ROB-processed register of C-class flares and above from the last six days, as recorded at PROBA2. This can be seen to be dominated by AR3514 streaking across the northwest disc.

Solar Radiation Storms - (High Energy Protons):

The M1.1 from near 90W at 17/2017UTC in theory carries a 10% chance of having produced an eventual proton enhancement in excess of S1, however this ought to have started to show its hand by the issue time of this document, and this flare is not considered likely to have provided any additional risk.

The high energy (greater than 10MeV) proton flux observed by GOES16 has otherwise been on a downward trend after peaking at S1 late on 15 December in response to activity from AR3514. The observed spectra were relatively soft, with 50 and 100MeV protons unmoved, despite the westward emission location from the X and M-class flares. The breach of S1 was not seen at GOES18 in otherwise very similar spectra, perhaps implying a local effect for GOES16.

Flux levels are now very close to Background, and the risk of further breaches of S1 should now gradually reduce as AR3514 rotates further away from the west limb.

Radiation Storms	**Level (cm^{-2} sr^{-1} s^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ S1**	No	15	10	10	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

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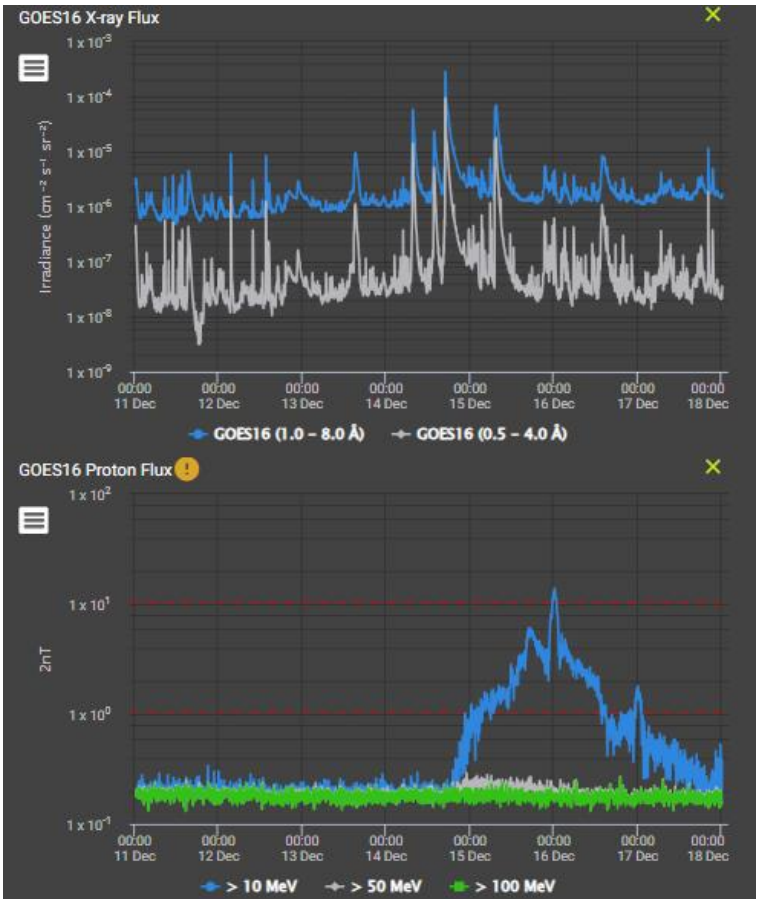
Figure 4: Past week in GOES16 X-ray flux and resulting high energy proton flux, peaking with a 13pfu S1 around the turn of the UTC day 15 into 16 December, a response to M and X-class flares from AR3514.



High Energy Electrons Event (≥ 2MeV):

High energy electron flux is currently mostly at Normal Background levels, and is expected to remain so in the immediate term. The CME effects from Sunday 17 December are likely to be compressing the Van Allen belts over the next 24 hours or so, however there is then a window for recovery between these effects waning and the fast wind from CH82 arriving on Tuesday 19 December. This fast wind and a potential further CME into the 20 December are then likely to suppress levels at GEO once again for a time, but with the eventual easing probably allowing for the peak risk of Active fluence for the forecast as a whole - perhaps a Chance by later Thursday 21 December.

GEO Electron Environment	**Level (cm^{-2} sr^{-1} day^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	20	5	40
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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